EVIDENCES OF CONTEMPORARY TECTONIC ACTIVITY ALONG THE EASTERN GULF OF CADIZ CONTINENTAL SHELF AND UPPER SLOPE (SW IBERIAN PENINSULA)

Evidencias de actividad tectónica contemporánea en el sector oriental de la plataforma continental y talud superior del Golfo de Cádiz (SO de la Península Ibérica)

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Resumen: La interpretación de una serie de registros de sísmica de muy alta resolución con ecosonda paramétrica TOPAS obtenidos en las campañas CADHYS0713, INDEMARES/CHICA1011 y ARSA 0313 en el sector oriental de la plataforma continental y talud superior del Golfo de Cádiz entre los 50 y los 400 m de profundidad, ha permitido identificar una serie de estructuras tectónicas que deforman tanto los depósitos de edad Holoceno y Pleistoceno Superior, como la superficie del fondo . Estas unidades estratigráficas se han identificado sobre la Superficie Transgresiva Posglacial, datada en 18 ka. Las principales estructuras identificadas son fallas normales y fallas inversas, cuya actividad se ha relacionado con fases de elevación de estructuras diapíricas de naturaleza salina que se extienden desde zonas emergidas hasta zonas distales del margen continental del Golfo de Cádiz.

Palabras clave: Plataforma continental, Pleistoceno y Holoceno, sísmica de alta resolución, Golfo de Cádiz

Abstract: Very *high resolution parametric echosounder (TOPAS) data interpretation obtained during CADHYS0713, INDEMARES/CHICA1011 and ARSA0313 cruises along the middle, external shelf and upper slope of the eastern Gulf of Cadiz between 50 and 400 m depth has allowed us the identification of several active tectonic structures acting since the Holocene. To date this activiy, it have been identified along the study area three postglacial discontinuities, Postglacial Trangressive Surface (TS) of 18 ky BP; the maximum flooding surface (MFS) of 6.5 ky; and the 3.5 ky Mid highstand deposits surface (MHS). Active normal and reverse faults have been identified whose recent activity is closely linked to the uplift episodes of salt diapirs structures from onshore to distal areas of the continental margin.*

***Key words**: Continental shelf, Pleistocene and Holocene, high resolution seismic, Gulf of Cadiz*

INTRODUCTION

During the last years numerous authors have been studied the geology and geodynamic of the Gulf of Cadiz continental margin, mainly along the continental slope (Gràcia et al., 2003, Medialdea et al., 2004). Nevertheless the knowledge of the tectonic processes along the continental shelf of this margin is still limited. The main contribution of this paper is the presentation of new data about the contemporary tectonics along the eastern sector on the Gulf of Cadiz continental shelf, marked by the salt diapiric activity during Late Pleistocene and Holocene times. In this sense, the interpretation of very high resolution reflection seismic profiles acquired with a parametric subbottom profiler (TOPAS) allowed us to identify and map tectonic structures that deform the most recent stratigraphic record.

GEOGRAPHIC AND GEOLOGICAL SETTING

The study area is located in the middle and outer continental shelf and in the upper slope of the NE sector of the Gulf of Cadiz margin, between the longitude 6º27' and 6º28' W and latitude 36º22' and 36º04' N. The bathymetry ranges from 50 to 400 m depth (Figure 1a and 1b). This area is characterized by a general elevation regarding to the adjacent margin ones, highlighting submarine channels towards the slope with a NE-SW direction, as well as outcrop of Pleistocene deposits.

From a physiographic perspective, the Gulf of Cadiz continental shelf exhibits an average width of 50 km and a gentle depth gradient, with a shelf boundary between 150 and 200 m depth. In the study area, the continental shelf is 40 km wide and has approximately 0.25º gradient. The upper slope is developed between 150 and 400 m depth and their gradients range between 1º and 3º. The oceanographic regime is controlled mainly by the anticyclonic circulation of the Superficial Atlantic Water (SAW) which moves from west towards the southeast (Nelson et al., 1999; Hernández-Molina et al., 2003).

The geological configuration of the Gulf of Cadiz is strongly influenced by their geodynamic evolution since Miocene to nowadays. The emplacement of faults and folds in the Betic-Rif belt front in this area, which is represented by the Gulf of Cadiz Allochtonous Unit (Medialdea et al., 2004), and the general NW to WNW directed oblique-compressive regime between the plates of Eurasia and Nubia

(Maldonado et al., 1999; Gràcia et al., 2003; Medialdea et al., 2004; Medialdea et al., 2009) are the main factors which are controlled the tectonic geometry. The study area is located from S to N between the Flysch Units Complex and the External Betic domain. The last domain is constituted by the Subbetic Units and the Gulf of Cádiz Allocthonous Complex (Medialdea et al., 2004)

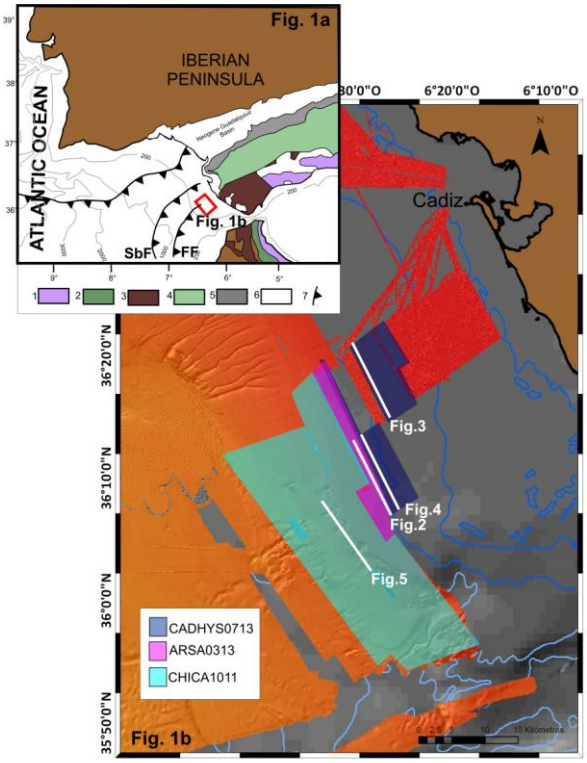

Figure 1a and b. The study area location, along the mid an external continental shelf of the NE Gulf of Cádiz margin, between 50 and 400 m depth is highlighted with colors boxes. Legend of Fig. 1a: 1) Rifean-Betic Internal Zone Units; 2) Ridge Complex; 3) Flysch Units; 4) Betic Rifean External Zone Units; 5) Guadalquivir Olistostromic Units; 6) Neogene Basins; 7) Cadiz Allocthonousb Unit Front; SbF: Subbetic Units Front; FF: Flysches Units Front Rodero, 1999 modified)

Figuras 1a y 1b. Localización de la zona de estudio, enmarcada con cuadrículas de varios colores, a lo largo de la plataforma media y externa del sector NE del Golfo de Cádiz, entre 50 y 400 m de profundidad. Leyenda de la Fig. 1a: 1) Zonas Internas Bético-Rifeñas; 2) Complejo de Dorsal; 3) Unidades del los Flysches; 4) Zonas Externas Béticas; 5) Unidades Olistostrómicas del Guadalquivir; 6) Cuencas Neógenas; 7) Frente de la Unidad Alóctona de Cádiz; SbF: Frente Subbético; FF: Frente de los Flysches (Modificado de Rodero, 1999).

METHODS

A database of very high resolution parametric profiles (TOPAS PS18) has been used. The profiles used for this contribution were obtained in 2013 during CADHYS0713 and ARSA0313 cruises onboard Spanish R/V Margalef and Miguel Oliver, within the framework of CADHYS project (P08-RNM-03581) and the Spanish Oceanographic Institute Project ARSA respectively. And in 2011 during INDEMARES/CHICA1011 onboard the Spanish R/V Vizconde de Eza within the framework of the European project LIFE+ INDEMARES/CHICA. A total of 103 seismic lines with a NNW-SSE orientation, parallel to the coast line were obtained covering approximately an extension of 1100 km^2.

In order to date the relative actual tectonic activity of this area, it has been identified several Holocene stratigraphic discontinuities previously defined by Fernández-Salas et al., 2008 and have been used to identify and to control the tectonic relative activity in the septentrional sector of this continental shelf (Sánchez Guillamón et al., this issue). The Late Pleistocene and Holocene discontinuities identified are the 18 ky BP Posglacial Trangressive Surface (TS); the 6,5 ky maximum flooding surface (MFS) and the 3,5 ky Mid high stand deposits surface (MHS) horizons.

RESULTS AND DISCUSSION

The structural interpretation of a set of very high resolution seismic data has enabled the characterization of folds and a faults system with recent tectonic activity along the middle-external continental shelf and upper slope. The faults system exhibit normal and reverse geometries. The contemporary activity of these structures is highlighted by the strong TS and seafloor surfaces deformation. The active tectonics in this area is in agreement with previous studies in onshore-offshore of nearby areas (Gracia et al., 2008, Vázquez et al., 2010,) and it is mainly associated to the moderate diapirism activity during Late Pleistocene and Holocene times (Figure 2).

On the external shelf and upper slope NE-SW normal faults have been identified which have 0.7 to 3 km long. They are interpreted as crestal faults located over a main diapir with similar trend. The tectonic transport direction of normal faults located to the north of diapir is towards NNW, while in normal faults located to the south of diapir the tectonic transport direction is towards SE. Vertical offsets up to 3 m cutting the Upper Pleistocene sedimentary units has been observed reaching the surface and raising 1 m from the seafloor to the north of diapir (Fig. 3).

Reverse faults have also been identified in this area. They exhibit a NE-SW orientation and ranging between 0.8 km and 4 km long. These features are related to diapirism and locally deform their internal structure and the seafloor, for instance 1.5 m in the northern hanging wall (Fig. 2 and 4).

These structures allow us to identify several recent active episodes of diapirism during the Late Pleistocene and Holocene. Locally, Holocene sedimentary units and seafloor tilting have been observed both on shelf and upper slope as the result of the contemporary uplift of diapirs (Figure 5). The elevation of this margin area could partly favor the erosive processes action and the development of morphological features like channels down slope.

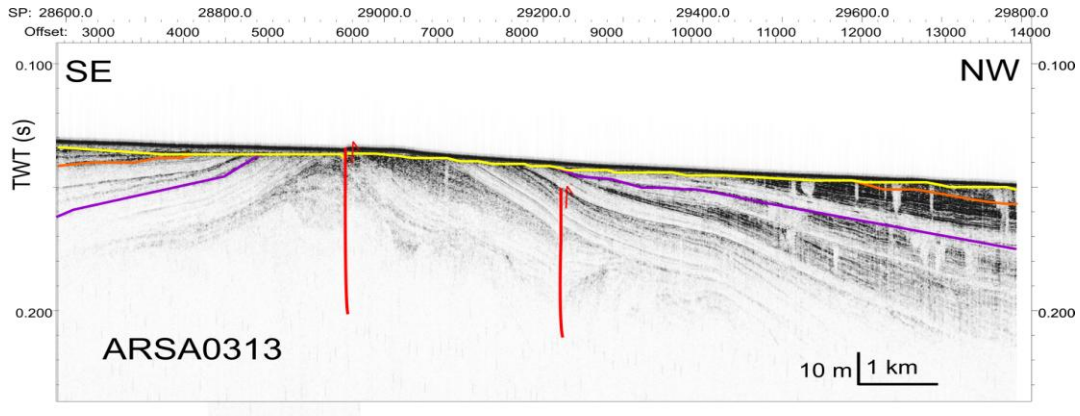

Figure. 2. Seafloor and Late Pleistocene deposits deformation show the current diapiric uplift along the continental shelf study area. Seismic Horizon legend: yellow, MHS; in orange MFS; in purple TS.

Figura. 2. La deformación tanto de la superficie del fondo como de las unidades Pleistocenas tardías ponen de manifiesto la actividad diapírica actual. Interpretación de discontinuidades: amarillo, MHS; en naranja, MFS; en violeta, TS.

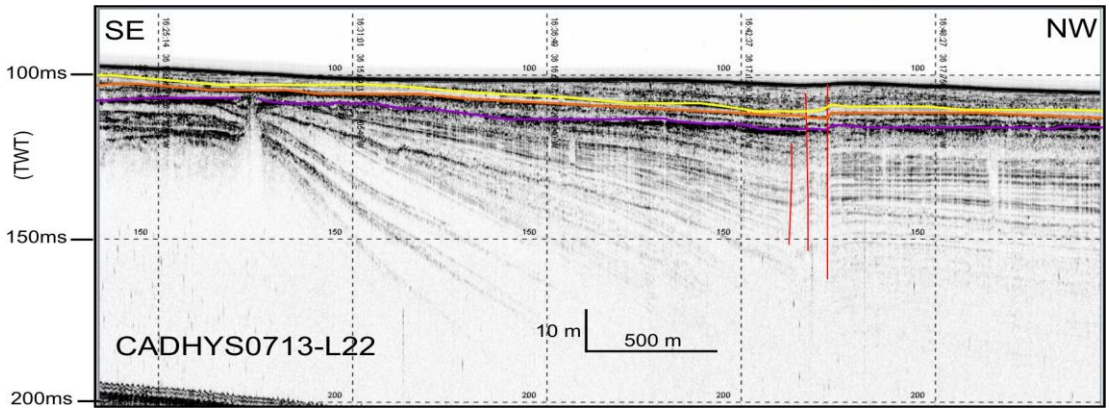

Figure 3. High resolution reflection seismic profile interpretation showing the normal faults geometries that deform the Pleistocene and Holocene deposits, as well as the seafloor. Same legend for horizons than Figure 2.

Figura 3. Interpretación de un perfil sísmico de alta resolución en el que se observan fallas normales con hundimiento hacia el S que deforman tanto las unidades Pleistocenas como todo el registro sedimentario Holoceno, así como la superficie del fondo. La leyenda para los horizontes es la misma que la Figura 2.

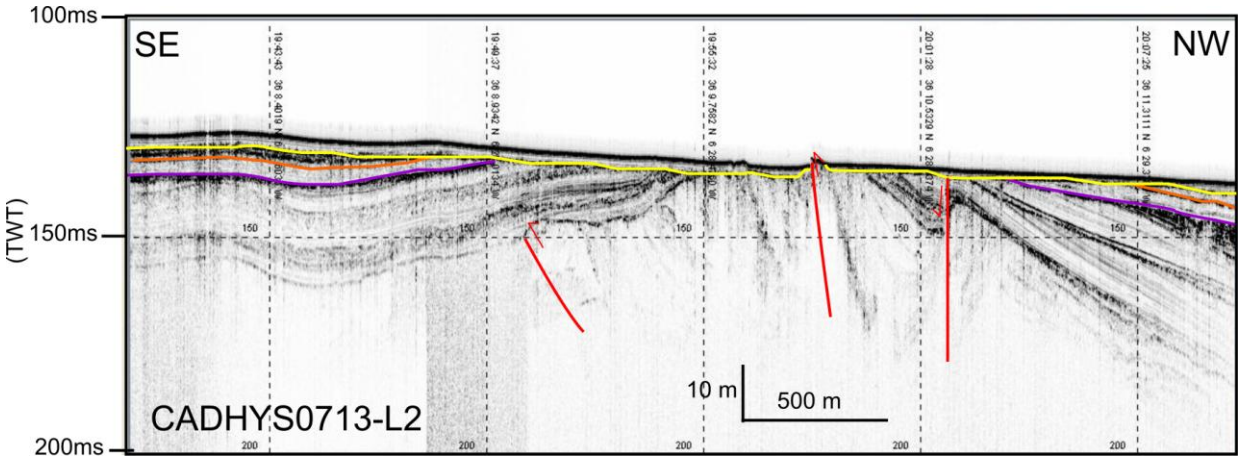

Figure. 4. High resolution reflection seismic profile interpretation showing reverse fault and folds that deform Pleistocene deposits and the strongly eroded seafloor as well as a normal fault northwards to the reverse faults. Same legend for horizons that Figure 2.

Figura. 4. Interpretación de un perfil sísmico de alta resoluciónen el que se observan fallas inversas y pliegues que deforman tanto los depósitos de edad Pleistocena, como la superficie del fondo fuertemente erosionada, así como una estructura de falla normal situada al norte de las fallas inversas. La leyenda para los horizontes es la misma que la Figura 2.

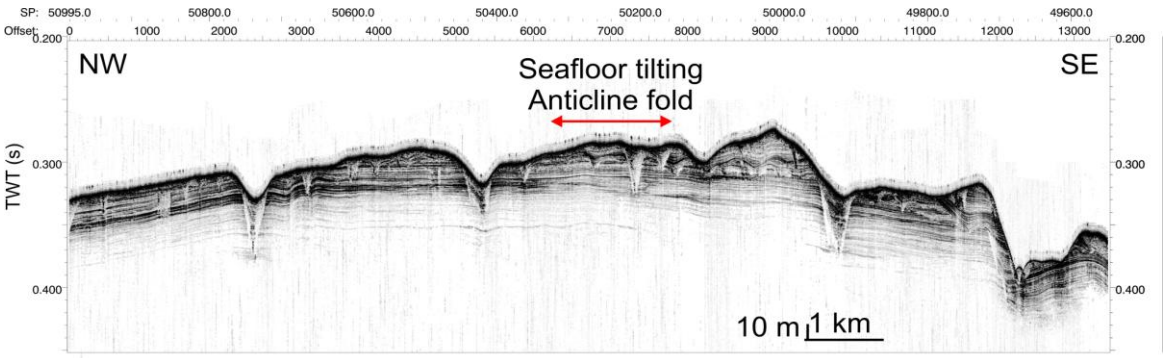

Figure 5. High resolution seismic profile. It is observed the deformation and channel excavated on the upper slope.

Figura 5. Perfil sísmico de alta resolución en el que se puede observar la deformación y canales excavados sobre el talud superior.

CONCLUSIONS

The tectonic structures described above along the eastern sector of the Gulf of Cadiz continental shelf reveal the Late Pleistocene-Holocene tectonic activity that affects all the geological domain that constitute this margin. All the tectonic structures are mainly caused by compressional episodes associated with the WNW-ESE oblique-convergence between Eurasian and Nubian plates.

The second factor of tectonic activity must be caused by the salt and shale diapir deformation. These diapir structures, located both down the continental shelf and the upper slope, are related to the Gulf of Cadiz Allochtonous Units. These units have a plastic behavior and are more likely to be reactivated under the tectonic stress action and produce the contemporary diapirism uplift.

The current configuration of the eastern sector of the Gulf of Cadiz continental margin is mainly controlled by tectonic, halokinetics and erosional processes close to the hydrodynamic regime. Nevertheless, the tectonic processes could be probably trigger the other processes

This contribution is the first high resolution seismic imagery obtained on the eastern sector of the Gulf of Cadiz continental shelf. The interpretation of very high resolution parametric profiles and the calibration of the stratigraphic record allow to have a more detailed knowledge of the contemporary tectonic events. In this sense a main effort is needed to support a detailed datation of postglacial stratigraphic units on the continental shelf.

Acknowledgements: This research has been supported by CADHYS project (P08-RNM-03581), European project LIFE+INDEMARES/CHICA and Spanish Oceanographic Institute project ARSA. The comments of an anonymous reviser haven improve the last version.

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